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10/518340

ROCK BOLTING SYSTEM

DT01 Rec'd PCT/PTC 17 DEC 2004

Field of the Invention

The present invention relates to rock bolts, whether the bolt tendon is formed from a flexible cable or a rigid rod, the grout delivery tube for such bolts, and the fabrication of such tubes.

Background Art

Rock bolts are widely used in civil engineering and mining applications to stabilise rock strata.

Essentially a blind hole or bore is drilled in the rock and a rock bolt having an anchor at its far end is inserted into the hole. The anchor is operated so as to grip the far end of the hole and secure the bolt in the hole. The bolt is surrounded by a tube and grout is pumped into the gap between the bolt and the tube. The grout passes down the tube until it reaches the anchor and then begins to flow back out of the hole between the interior of the hole and the exterior of the tube. The operator ceases to pump grout when the returning grout is observed escaping from the hole. The grout hardens and provides a force transmitting structure between the interior of the hole and the length of the rock bolt. In this way the steel bolt can react effectively against any movement in the surrounding ground.

Object of the Invention

The object of the present invention is to provide an improved tube, a cable bolt incorporating the tube, bolt fittings and fabrication techniques all of which together constitute an improved rock bolting system.

Summary of the Invention

In accordance with the first aspect of the present invention there is disclosed a tube for cable or rod bolt applications, said tube being extruded from plastics material and deformed beyond its yield point at a plurality of longitudinally spaced apart locations, along the length of the tube, each said deformation occurring in at least two different directions.

In accordance with the second aspect of the present invention there is disclosed a rock bolt having a tendon located within the above defined tube.

In accordance with a still further aspect of the present invention there is disclosed an end fitting for a rock bolt, said fitting comprising a barrel having a substantially flat front end, a rear end, a curved side wall, and a longitudinal axis, a cable passageway passing between said front and rear ends, and a grouting orifice extending from said front end into said cable passageway.

In accordance with a fourth aspect of the present invention there is disclosed a method of fabricating a tube for a rock bolt, said method comprising the step of radially deforming the side wall of said tube beyond its yield point in at least two different directions, at each of a plurality of longitudinally spaced locations.

In accordance with another aspect of the present invention there is disclosed a rock bolt for use in poor ground conditions, said bolt having a near end and a far end, anchor means at said far end to anchor the far end adjacent the base of a blind hole formed in said ground, and tension means at said near end to tension said bolt after said far end has been anchored, wherein said anchor means comprises at least two anchor devices, each known per se, and connected in series adjacent said far end.

In accordance with a still further aspect of the present invention there is disclosed a method of securing a rock bolt in poor ground conditions, said method comprising the steps of:

providing at least two anchor devices, each known per se, at the far end of said rock bolt,

inserting said rock bolt into a blind hole drilled in said ground,

activating all said anchor devices, and

tensioning said rock bolt.

Preferably, following tensioning of the rock bolt, the bolt is surrounded with grout.

Brief Description of the Drawings

The prior art and the embodiments of the present invention will now be described with reference to the drawings in which,

Fig. 1 is an exploded perspective view of a prior art rock bolt prior to installation,

Fig. 2 is longitudinal partly cross sectional view through the rock bolt of Fig. 1 as installed,

Fig. 3 is a perspective view of the tube of the preferred embodiment,

Fig. 4 is an end view of the tube of Fig. 3,

Fig. 5 is a plan view of the tube of Fig. 3,

Fig. 6 is a side elevation of the tube of Fig. 3,

Fig. 7 is perspective view of the near end of a cable bolt incorporating the tube of Fig. 3-6,

Fig. 8 is a plan view of the cable bolt end of Fig. 7,

Fig. 9 is an end elevation of the arrangement of Figs. 7 and 8,

Fig. 10 is a longitudinal cross sectional view taken along the line X–X of Fig. 9,

Fig. 11 is an end view of the free end of the cable bolt of Fig. 7,

Fig. 12 is a perspective view of another embodiment of the end fitting of the cable bolt of Fig. 7,

Fig. 13 is an end view of the fitting of Fig. 12,

Fig. 14 is the opposite end view of the fitting of Fig. 12,

Fig. 15 is an alternative perspective view of the fitting of Fig. 12, and

Fig. 16 is a longitudinal partly cross-sectional view of the far end of a rock bolt.

Figs. 1 and 2 illustrate a prior art rock bolt known as the "CT bolt" which is generally as described in Australian Patent No. 669,393 (Application No. 49856/93 and WO 94/05900). The CT bolt 1 has a solid steel tendon 2 with an anchor 3 (illustrated only in a general cylindrical form in Fig. 1) located at its far end. A tube 4 having a plurality of papillae 13 surrounds the tendon 2 and the near end of the CT bolt 1 has a washer plate 5, a hollow dome ball 6, and nut 7.

As seen in Fig. 2, a blind hole 8 is drilled in the ground 9 and the CT bolt inserted therein. The anchor 3 is expanded so that it grips the interior of the hole 8 thereby locating the CT bolt 1 in its final position. The bolt can be tensioned by means of the nut 7 engaging a thread on the near end of the bolt. Then a flowable hardenable cementitious grout 10 is pumped into a small grout orifice 11 from where the grout passes between the tendon 2 and the interior of the tube 4. As the grout moves down the hole 8 between the tendon 2 and tube 4, air is being expelled from the hole 8 by passing between the interior of the hole 8 and the exterior of the tube 4. Eventually the grout 10 reaches the end of the hole 8 and the anchor 3 and then passes between the hole interior and the external surface of the tube 4. Eventually grout is expelled from the hole 8 adjacent the washer plate 5 indicating to the operator to cease pumping grout.

The purpose of small papillae 13 formed in the tube 4 is to provide a keying mechanism to enable longitudinal shearing forces to be transferred between the ground 9 and the tendon 2 by means of the grout 10.

Current methods of deforming the tube 4 involve processing the tube when it is hot and soft immediately after being formed and upon the tube exiting from the plastic extruder which creates the tube 4 from raw granular material. The tube in this soft and hot state enters another machine termed a "corrugator" which has a series of external moulds into which the tube is forced by compressed air from the inside, or vacuum applied from the outside, or both, so that the hot tube takes the shape of the moulds.

Such corrugators are known to produce corrugated plastic drainage pipe and corrugated swimming pool hose. Corrugated tube is known to be used in relation to rock bolts but suffers from a number of disadvantages. Firstly, the corrugating process is slow and therefore relatively expensive. Secondly, although the corrugated tubing has the advantage of being flexible and resistant to crushing, the geometry of corrugated tubing creates a number of disadvantages. In particular, the close corrugations, extending in an annular fashion relative to the axis of the tube,

commonly trap air when the grout material is pumped therepast. These pockets of trapped air very substantially reduce the capacity of the tube to transfer mechanical loads. A similar problem is that the small amount of grouting material in the annular corrugations does not have the strength, because of its small mass and volume, to resist the shearing forces experienced in use. Therefore corrugated tube easily shears the grout from one annular deformation to the next.

In addition, the annular deformations of the corrugated tube catch on many types of objects during the installation procedure such as load plates, wire mesh, the parts of the installing machinery, and the like, all of which can lead to damage of the tube. If the corrugated tube is damaged the bolt can be uninstallable and/or unable to be grouted. This is because a hole in the tube will effectively "short circuit" the grouting procedure and result in grout not being delivered to the full length of the hole.

Whilst the known corrugated tube is flexible, and thus is able to be looped into a coil, the tube 4 of Figs. 1-2 is not. This tube, for example fabricated for installation in 45mm bore holes, is substantially round and has a diameter of approximately 35mm. Each papilla 13 is formed as one of three outwardly extending bumps spaced equally around the tube at locations spaced apart by approximately 50mm along the tube. The maximum "diameter" of the tube at the location of the papillae is approximately 42mm. The tube 4 is produced on a corrugator machine but without producing corrugations. The tube is stiff and thus cannot be bent or coiled up as this results in the tube kinking and/or breaking. The papillae 13 on the tube 4 are also susceptible to being sheared off if the tube is handled roughly prior to installation.

The cost of the tube 4 is approximately three times the cost of similar tube (so called polytube made from high density polyethylene (HDPE)) used extensively in irrigation applications. It would therefore be desirable if this inexpensive tubing could be used for rock bolting applications.

Figs. 3-6 illustrate a deformed irrigation polytube 14 which has been deformed in such a way as to still retain its flexibility and thereby permit the polytube 14 to be coiled or looped into a coil. The polytube 14 is deformed by being placed between

forming tools, which yield the material of the tube 14 in small areas. The yielding stops the material of the polytube 14 from returning to its original configuration. With reference to Fig. 3, in one embodiment, the tube 14 is compressed by having inwardly oppositely directed forces F1 and F2 applied to its "sides" whilst substantially simultaneously two inwardly oppositely directed forces F3 and F4 are applied to its "top" and "bottom" (spaced from but adjacent to the location of the F1 and F2 forces) so as to create generally rectangular bulges 17 having triangularly shaped slopes 18.

Because the yielding zones 50 which create the bulges 17 are arranged in sequential fashion along the length of tube 14, these deformed patterns remain deformed and provide a mechanism to enable load transfer from the bolt to the surrounding ground via the grouting applied to both sides of the tube 14. In particular, the shape of the bulges 17 provide a number of advantages in that they reduce the occurrence of damage prior to, or during, installation. Similarly, the shape of the bulges 17 reduces the risk of air voids developing during the grouting operation.

Because the tube 14 thus deformed is able to be rolled into a coil, long lengths of rock bolt utilising steel cable as the rock bolt tendon, rather than solid steel rod, are able to be formed and also coiled prior to installation. This provides substantial advantages as regards packaging and handling of the bolts prior to installation. It also allows installation of long post grouted bolts in limited access areas.

Figs. 7-11 illustrate the near end of such a cable bolt, the far end being substantially conventional. As seen in Figs. 7-11, a cable bolt 21 has a cable 22 which passes through the polytube 14 and is provided with a barrel like end fitting 26 at the near end. The barrel 26 has a flat end face 28 and a domed front face 29 with a substantially cylindrical side wall 30. A grouting orifice 31 is formed in the end face 28 and, as seen in Fig. 10, leads into a grouting passage 32 which is inclined to the longitudinal axis of the polypipe 14 and cable 22.

In addition, the barrel 26 has a main passage 34 which includes a frusto-conical wedge 35 which acts a gripping mechanism for the cable 22. Thus the grouting

passage 32 delivers grout above the cable gripping wedges 35 which hold the barrel 26 to the cable 22.

That is, after the hole in the ground has been drilled, the far end of the cable bolt 21 (not illustrated) is inserted into the hole and an anchor at the far end is activated so as to fix the far end of the bolt in the hole. Then the cable 22 can be placed under tension and the barrel 26 moved towards the far end until the barrel 26 comes into contact with a washer plate, or the like (not illustrated).

With the cable 22 thus tensioned, grout is able to be pumped through the grouting orifice 31 and grouting passage 32 into the interior of the polytube 14. The grout then travels along the length of the cable bolt 21, passes out the end of the polytube 14 and returns back towards the barrel 26 this time passing between the interior of the hole and the exterior of the polypipe 14.

It will be appreciated that the main passage 34 is not concentric with the cylindrical side wall 30 and thus at the near end of the cable bolt 1 the cable 22 is not concentric with the longitudinal axis of the tube 14.

Figs. 12-15 illustrate a second embodiment of a barrel 46 in which the front face 39 is flat. The end face 28 and grouting orifice 31 are substantially as before.

The foregoing describes only some embodiments of the present invention and modifications, obvious to those skilled in the art, can be made thereto without departing from the scope of the present invention. For example, the bulges 17 in Figs. 3-10 extend in two directions which are substantially perpendicular to each other. It is also possible to arrange to have the bulges extend in three directions which are approximately 120° apart but that the longitudinally adjacent set of bulges should be rotated by 60° relative to the tube axis so that those bulges extend intermediate the bulges of the adjacent deformation. This is thought to assist shear load transfer.

In addition, the end fitting or barrel 26, 46 (in addition to being relatively inexpensive to manufacture) can also be used in a cable or rod bolt without the outer plastic tube 4,

14. In this arrangement a breather tube passes through the grouting orifice 31 and grouting passage 32 and then extends alongside the bolt to its far end. Under this arrangement grout is introduced between the bolt and hole and moves towards the far end of the hole but the air displaced by the grout is pushed out through the breather tube. Eventually the grout reaches the far end of the hole and then beings to fill the breather tube. The grouting process is stopped when the grout is seen returning through the breather tube.

Turning now to Fig. 16, the far end of a rock bolt 51 intended for use in poor ground, such as sandstone, is illustrated. In this particular embodiment the cable tendon 52 is formed from multistrand steel cable 22, but a solid tendon could equally be used.

Mounted on the cable 22 are a pair of spaced apart conventional shell anchors 53 such as those disclosed in Australian Patent Application No. 22992/02 which each include a restraining device in the form of a rupterable band 57. The anchors 53 are able to be expanded in known fashion by being spring loaded. In this way the two pivoted halves of the anchors 53 pivot outwardly to grip the interior of the surrounding blind hole 8.

The installation procedure is as follows. The rock bolt 51 is inserted fully into the blind hole 8. The spring expansion shells grip the sandstone surrounding the blind hole 8 with sufficient combined force to enable the cable 22 to be tensioned. Then the entire hole 8 is grouted in a single operation. The entire operation takes only a few minutes.

This is to be contrasted with the previous procedure where, following insertion of a rock bolt in poor ground, a sophisticated grout delivery system was used to grout only the far end of the rock bolt. Only after this grout had cured was the rock bolt tensioned. Then the remainder of the bolt was grouted. This prior art process took several weeks.

The foregoing describes only some embodiments of the present invention and modifications, obvious to those skilled in the art, can be made thereto without departing from the scope of the present invention.

The term "comprising" (and its grammatical variations) is used in the sense of "having" or "including" and not in the sense of "consisting only of".